WASTED

EUROPE'S UNTAPPED RESOURCE

An Assessment of Advanced Biofuels
from Wastes & Residues

Supported by:

ANALYSIS

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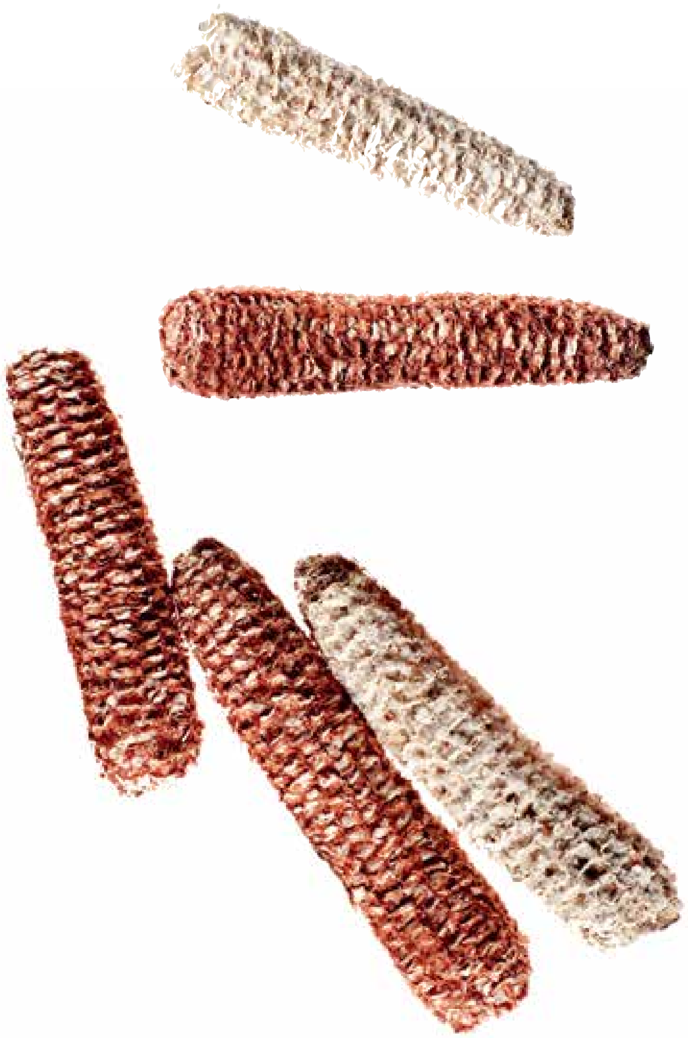
Summary



Key findings:

- If all the wastes and residues that are sustainably available in the European Union were converted only to biofuels, this could supply 16 per cent of road transport fuel in 2030. (Technical potential).
- If advanced biofuels from wastes and residues are sourced sustainably, they can deliver GHG savings well in excess of 60 per cent, even when taking a full lifecycle approach.
- Safeguards would be needed to ensure this resource is developed sustainably, including sustainable land management practices that maintain carbon balances and safeguard biodiversity, water resources and soil functionality.
- If this resource were utilized to its full technical potential, up to €15 billion of additional revenues would flow into the rural economy annually and up to 300,000 additional jobs would be created by 2030.
- While some combinations of feedstock and technology will require short-term incentives, others are close to being competitive and require little more than policy certainty.

There is a pressing need to transform the way in which society uses energy

Europe could cut the carbon-intensity of transport fuels, reduce spending on oil imports and boost the rural economy by developing sustainable advanced biofuels from wastes and residues.

There are currently concerns that wastes and residues are available in insufficient quantities to make a meaningful or cost-effective contribution to fuelling transport. This in-depth analysis concludes that advanced biofuels from wastes and residues, if mobilized in a sustainable manner, can make a sizeable contribution to reducing European dependence on imported oil.

This study starts with a precautionary approach and only focuses on wastes and residues that were viewed by all project partners as sustainable. The main conclusion is that if all the sustainably available resources were converted only to road transport fuel, the technical potential could equal 16 per cent of demand in 2030.

Commercializing this resource could also create hundreds of thousands of jobs, both in building and operating refineries and in collecting the resources to feed them.

Meanwhile, the potential CO_2 savings range from 60 to 85 per cent in most cases, making a significant contribution to EU climate goals.

The latest review of evidence by the Intergovernmental Panel on Climate Change (IPCC) reports with high confidence that rising levels of CO_2 are warming oceans, melting ice and turning oceans more acidic. Global average temperatures are projected to be 2.6-4.8° Celsius (C) higher than at present by the end of this century if emissions continue to rise at the current rate.

Although emissions from other sectors are generally falling, road transport is one of the few sectors where emissions have risen rapidly in recent years. The transport sector is on track to become the EU's biggest source of CO_2 by 2030 according to the European Commission.

While significant gains have been made in recent years to improve vehicle efficiency, there is also much that can be done to reduce the carbon intensity of energy used in transport. Alternative energy carriers, such as hydrogen, natural gas, biofuels and batteries are part of this picture, in cases where life cycle assessments (LCAs) show genuine CO_2 reductions.

Creating more advanced biofuels from wastes and residues, which might otherwise be left to decompose, offers one opportunity to reduce the carbon-intensity of transport fuels without creating significant impacts on food commodity markets or land resources. Such advanced biofuels also fulfill the role of improving European energy security and providing an additional revenue stream to farmers and forest owners.

Questions remain unanswered about the sustainability of "wastes and residues", many of which are not truly wasted, as they have existing uses that would be displaced by their use as biofuel feedstocks. Furthermore, there has been little research to date on what volumes of these wastes or residues might realistically be mobilized in an economically viable manner without unintended consequences.

Previous life cycle assessments have overlooked potentially important sources of emissions, such as soil carbon loss, any need to use extra fertilizer if removing residues and indirect emissions caused by diverting residues and wastes from their existing uses. The CO_2 savings from forest residues are complex to estimate, as there are uncertainties around their decomposition rate if left in forests or the impacts on soil carbon. The above issues are taken into consideration in this project by using a comprehensive carbon accounting approach. Equally pressing are questions about the costs and economics of the advanced technologies required to convert such wastes and residues into liquid transport fuels.

This project has shed light on such questions. An expert panel has been convened of environmental NGOs, energy analysts and companies with direct experience in technologies to produce advanced biofuels. These experts have examined the sustainability of converting wastes and residues to biofuels; the availability of the most sustainable resources; the economic impact if this resource is fully converted to transport fuel; and the business-case for doing so.

The project found that many advanced biofuels from wastes and residues can make a significant contribution to mitigating climate change, even when accounting for losses to soil carbon and the need for additional fertilizer. Forest residues, known as slash, were found to deliver CO_2 savings of around 60 per cent, provided steps are taken to minimize soil carbon losses. Savings might be found to be lower or higher depending on the accounting approach taken for emissions from decomposition of slash. Timber-processing residues such as sawdust were found to deliver savings of around 75 per cent while still accounting for displacement effects.

Higher greenhouse gas savings were found to come from agricultural residues, reaching 80 per cent in cases where indirect emissions due to displacement effects can be minimized. Municipal solid waste was found to deliver the highest greenhouse gas savings of all, well in excess of 100 per cent due to the possibility of avoiding decomposition to methane in landfill sites.

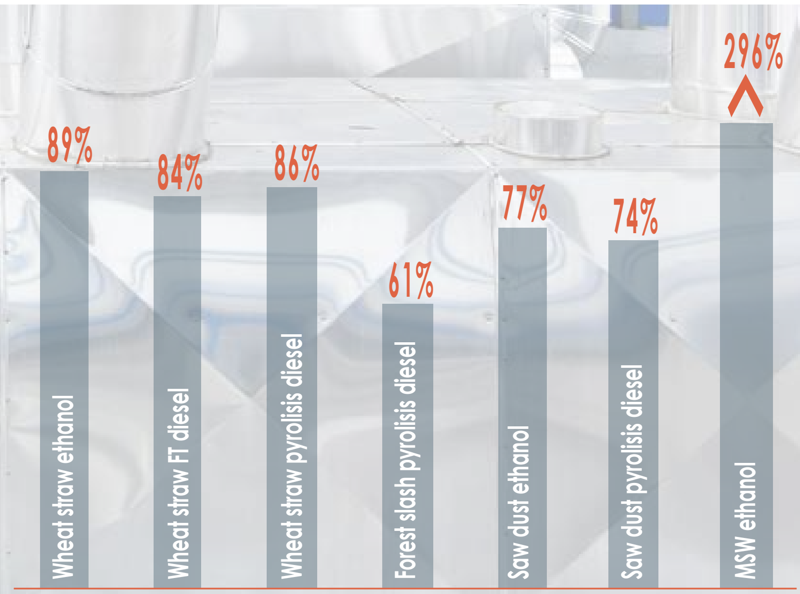
While Europeans generate around 900 million tonnes of waste paper, food, wood and plant material each year, only a fraction of this can be considered available, because much of this material has existing uses. A good example is sawdust, a "waste product" of timber production that is then used to make products such as fiberboard. The crop residues such as leaves and stalks that remain after cereal harvesting are "waste" from the perspective of food production, but are often used in other areas of agriculture including mushroom cultivation and bedding for livestock.

Some wastes and residues do not have industrial uses, but still provide valuable environmental services. The twigs and leaves left over from felling trees for timber return carbon and nutrients to the soil to support future tree growth. Some plant residues from harvesting food crops should be left on the ground to maintain soil structure and fertility.

Diversion of these materials from their current uses will have potentially negative secondary impacts, and therefore not all of the 900 million tonnes identified above can be mobilized. In general, it makes sense to use a cascading approach to wastes and residues, prioritizing re-use or recycling and acknowledging that the value of this material is more than simply its energy content. Accounting for the various industrial uses and sustainability restrictions, about a quarter of this cellulosic material is available for energy use between now and 2030 – about 220 million tonnes per year in total.

FIG 1.1

GHG savings potential from selected wastes and residues, compared to fossil diesel and gasoline



To put this into context, if all of Europe's sustainably available cellulosic biomass from wastes and residues was converted to transport fuel only, at current conversion rates, this technical potential would equal 16 per cent of road fuel in the EU by 2030.

Aside from fuels made from biogenic wastes and residues, there is also high potential to produce fuels from other feedstocks, such as used cooking oil or industrial waste gases. Currently, around 1.1 million tonnes of used cooking oil is being converted each year to low-carbon fuel in the EU, with potential to expand.

There are other more novel methods of producing advanced biofuels that utilize carbon-rich wastes from industry (such as the steel industry) that are beginning to scale to commercial levels. For example, today, steel production in Europe accounts for 8 per cent of the EU's CO_2 emissions. Production of ethanol from European steel mill residues alone could amount to around one-third of the EU's Renewable Energy Directive target of 10 per cent biofuels in transport by 2020 - around 8 million tonnes of oil equivalent (Mtoe) - according to some estimates.

Europeans generate around 900 million tonnes of waste paper, food, wood and plant material each year

FIG 1.2

Sustainable availability of wastes and residues in the EU in 2030

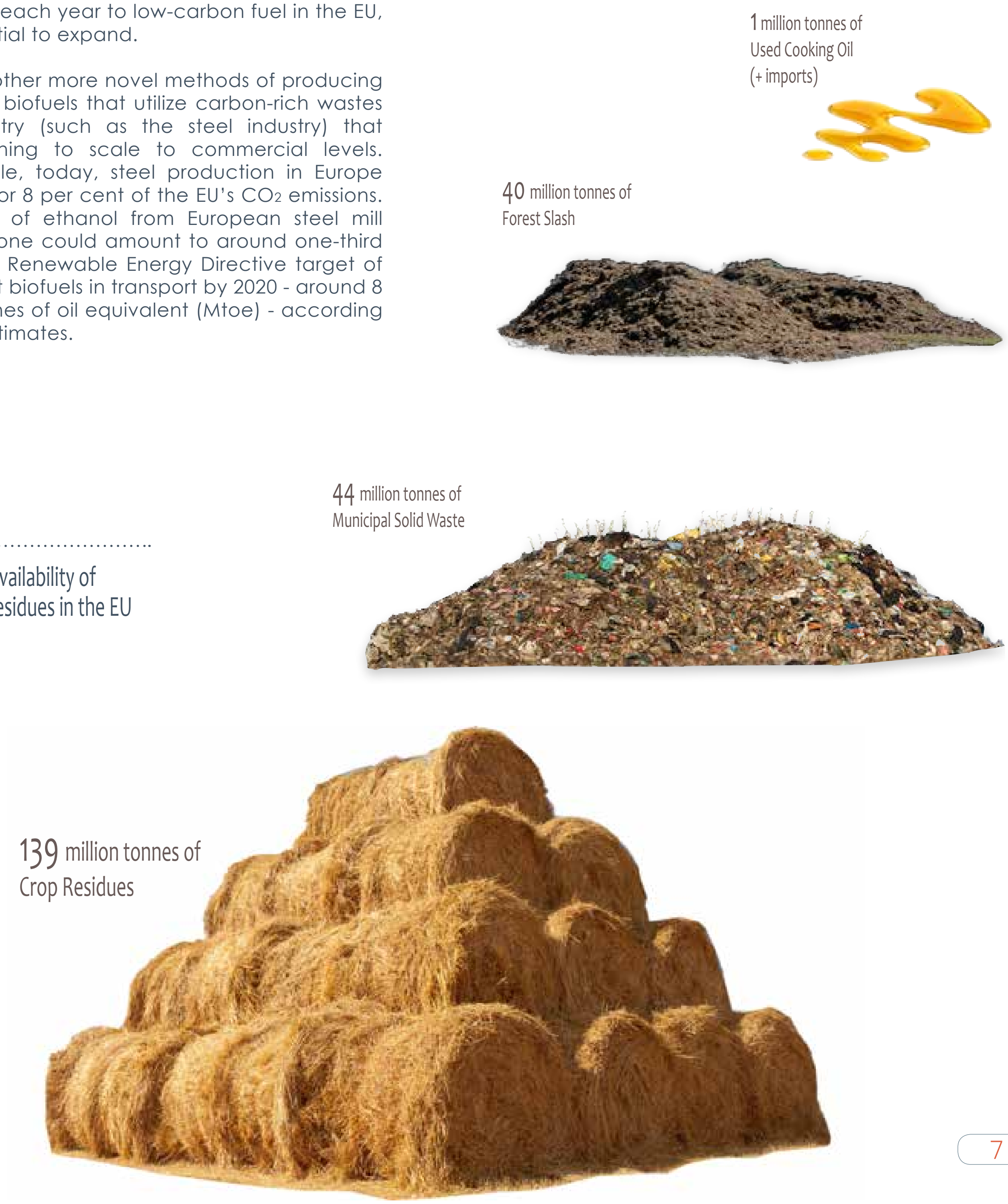
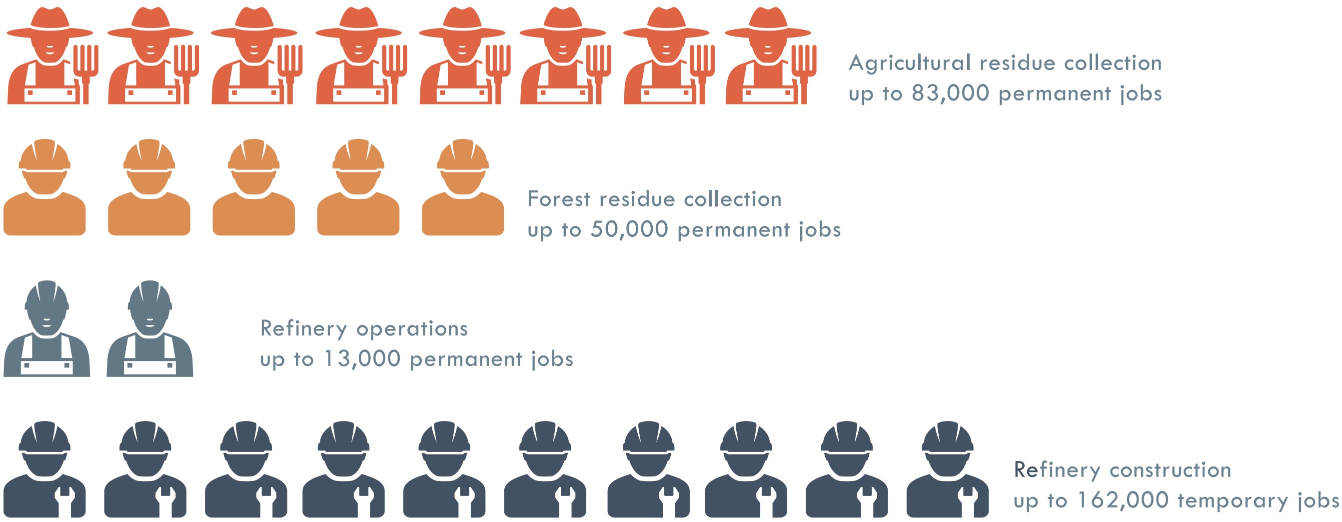


FIG 1.3

High-end estimates of additional employment from fully utilizing wastes and residues for conversion to advanced biofuels



The economic analysis in this project showed that many of the biofuel processes from wastes and residues could be mobilized with incentives at similar levels to those offered for the start-up of first generation biofuels from food crops. In some countries, the cost of agricultural residues might remain high at around €70-80 per tonne, posing a barrier to development, but there are many regions where costs are low. The economics of biofuels derived from municipal solid waste are more compelling, because of the relatively low feedstock cost.

It is not possible to determine how much of the technical potential for biofuels from wastes and residues will be met, but if investors realized the full technical potential identified here, up to €15 billion annually would flow into Europe's rural economy and up to 133,000 permanent jobs would be created in feedstock collection and transport. In addition, construction of these biofuel plants would require up to a further 162,000 temporary workers, and operation of these plants would create up to a further 13,000 permanent jobs.

It should be recognized that in reality there would also be competition for feedstocks within the energy sector – particularly for heating or electricity generation – so all of the above estimates should be understood as the upper limits. In the future, policymakers might need to consider the relative value of low-carbon mobility versus other demands on biomass resources.

On the other hand, the employment estimates represent only the direct jobs from feedstock collection, transport and processing. Additional indirect employment would flow though machinery suppliers, fuel suppliers and other ancillary industries, significantly increasing the overall impact in the EU.

Policy

The EU transport sector should be made more sustainable and lower in GHG emissions, primarily by improving energy efficiency and by reducing the carbon intensity of energy used in transport. There is a significant role in this transition for sustainably produced advanced biofuels, which can achieve the triple-win of cutting GHG emissions, improving energy security and boosting rural incomes.

This project has found that significant volumes of wastes and residues could be mobilized as biofuels without creating sustainability issues, provided safeguards are put in place. Many of the conversion pathways are already close to being competitive under the right conditions, but commercialization is being held back by policy uncertainty.

Commercialization now depends on political leadership and adequate policies, as it must be acknowledged that new innovative technologies are not yet cost competitive against their fossil alternatives, which still receive subsidies and have profited from over a century of optimization. Compounding the investment problem, the ongoing global financial and economic crisis has made investors and lenders more risk averse.

It is the role of policymakers to create policy certainty to foster innovation and to ensure that Europe achieves its environmental, economic and energy objectives. Full lifecycle accounting of emissions should be the tool that under-pins the mitigation of CO_2 from transport fuels. This should apply equally to all types of energy used in transport, including biofuels, hydrogen, fossil fuels and electricity.

Decarbonization targets, such as those in the EU Fuel Quality Directive (FQD), play a useful role in reducing the carbon-intensity of transport fuels in a cost-effective manner.

The FQD is the primary tool to reduce the carbon-intensity of transport fuels in 2020, and it should become increasingly ambitious beyond 2020.

Policy mechanisms to drive advanced biofuels into the market should be based on a thorough understanding of the volumes that are sustainably available and the indirect impacts that might occur from exceeding those volumes. Sustainability criteria must be in place to direct investment towards the most sustainable resources.

The organizations in this project therefore call on the European Parliament and Council of Ministers to deliver a sustainable, stable policy framework to decarbonize transport without delay.

Financial mechanisms will also play an important future role. The proposal to set up a new Public Private Partnership (PPP) to support bio-based industries is a step in the right direction. The estimated budget of this new initiative is €3.8 billion. The EU will contribute €1 billion from the Horizon 2020 programme budget, while industrial partners will commit €2.8 billion. The PPP should help demonstrate the efficiency and economic viability of advanced biofuels and other bio-based products.

The PPP under Horizon 2020 is a starting point that needs to be complemented with other funding sources in order to support advanced, first-of-a-kind commercial-scale biofuel plants. To do so, it would benefit from being combined with structural funds, particularly in Central and Eastern Europe. If such countries connect both funding opportunities, they will benefit from the innovation and economic opportunities while making use of structural funds that are currently underspent.

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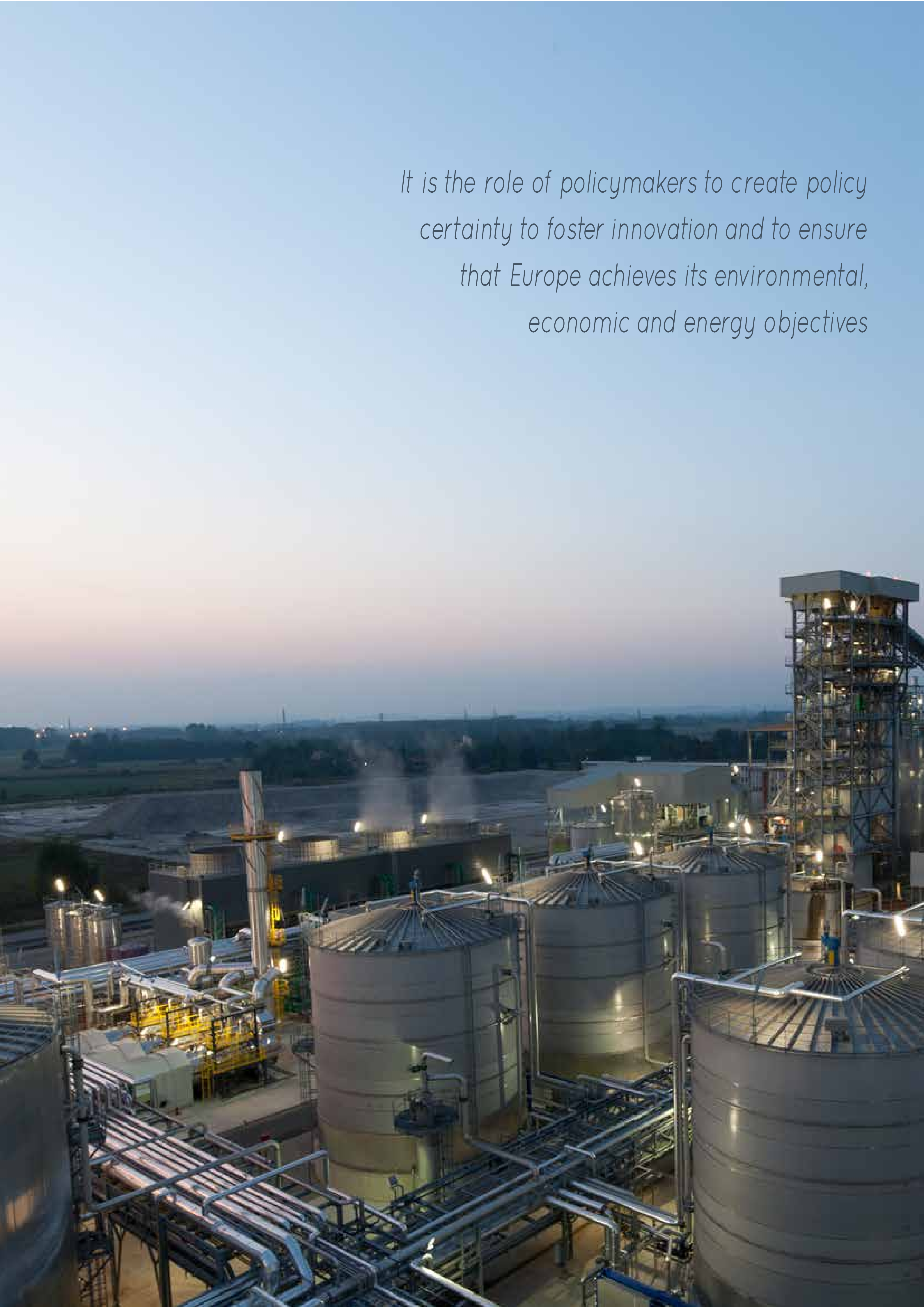


This chapter summarizes the project's findings on the GHG impact of biofuels from wastes and residues, which are described in greater detail in the paper "Assessing the climate mitigation potential of biofuels derived from residues and wastes in the European context" Baral A, Malins C, 2014 International Council on Clean Transportation

Sustainability

Advanced biofuels from wastes and residues have the potential to deliver high levels of GHG savings, but not all residues can be used sustainably.

This project only considers processes and feedstocks that would deliver significant GHG savings and does not look into feedstocks that were excluded due to sustainability concerns.

Biofuels from wastes and residues have been shown in previous Life Cycle Assessments (LCAs) to deliver high CO_2 savings. Estimates of carbon intensities have ranged from around -25 grams of CO_2 equivalent per megajoule (g CO_2e/MJ) at the low end to 40g CO_2e/MJ at the high end, compared to fossil fuels at around 84g CO_2e/MJ[1,2].

However, previous studies have often overlooked important sources of emissions, such as soil carbon loss, any need to use extra fertilizer if removing residues, and indirect emissions caused by diverting residues and wastes from their existing uses. For forest residues, there is also the issue that in some climates the residues decompose slowly and act as a temporary carbon sink. This has an impact on the potential carbon savings from mobilizing such residues for conversion to advanced biofuels.

The above issues are taken into consideration in this project by using a comprehensive carbon accounting approach. Three biofuel pathways are considered: biochemical ethanol, Fischer-Tropsch (FT)-diesel and pyrolysis diesel.

Biochemical ethanol processes use enzymes to break cellulose down into simple sugars, such as glucose, which are then converted into ethanol. To prepare the cellulosic feedstock for enzymic conversion, it is usually pre-treated with acid, alkali or steam.

During the FT process, feedstocks are gasified at temperatures of more than 700°C in the presence of limited amounts of oxygen and/or steam. This syngas is then converted into diesel and gasoline in the presence of catalysts and at temperatures of 150-300°C.

During pyrolysis, a feedstock is subjected to elevated temperatures in the absence of oxygen, resulting in bio-oil, bio-char, and pyrolysis gases. Bio-oil can be upgraded via hydrocracking to break it down into lighter hydrocarbons for diesel and gasoline.

GHG impact of harvesting

Agricultural and forest residues are important for returning carbon and nutrients to the soil and to help maintain soil fertility, reduce soil erosion and contribute to soil carbon. Hence, residue removal, even when done in line with sustainable practices, is likely to negatively impact soil carbon sequestration potential, a conclusion supported by both empirical and modelling studies[3]. The negative impact on soil organic carbon from residue removal can to some extent be mitigated by agricultural practices such as no-till, manure application or use of cover crops.

This project bases its assumptions for agricultural residues on a long-term empirical study where wheat straw removal was analyzed over a period of 22 years at a site in the UK[4]. It is acknowledged that the assumptions are based on limited data, and additional empirical evidence covering a wider geographical range would be extremely valuable.

Advanced biofuels from wastes and residues have the potential to deliver high levels of GHG savings, but not all residues can be used sustainably

When forest residues are left behind, especially in colder climates like Europe, decomposition occurs slowly, providing a temporary carbon sink if not harvested for biofuels. For example, between 2 and 30 per cent of the carbon stored in twigs and branches (known as slash) may still remain sequestered after a period of 25 years in Northern European countries[5].

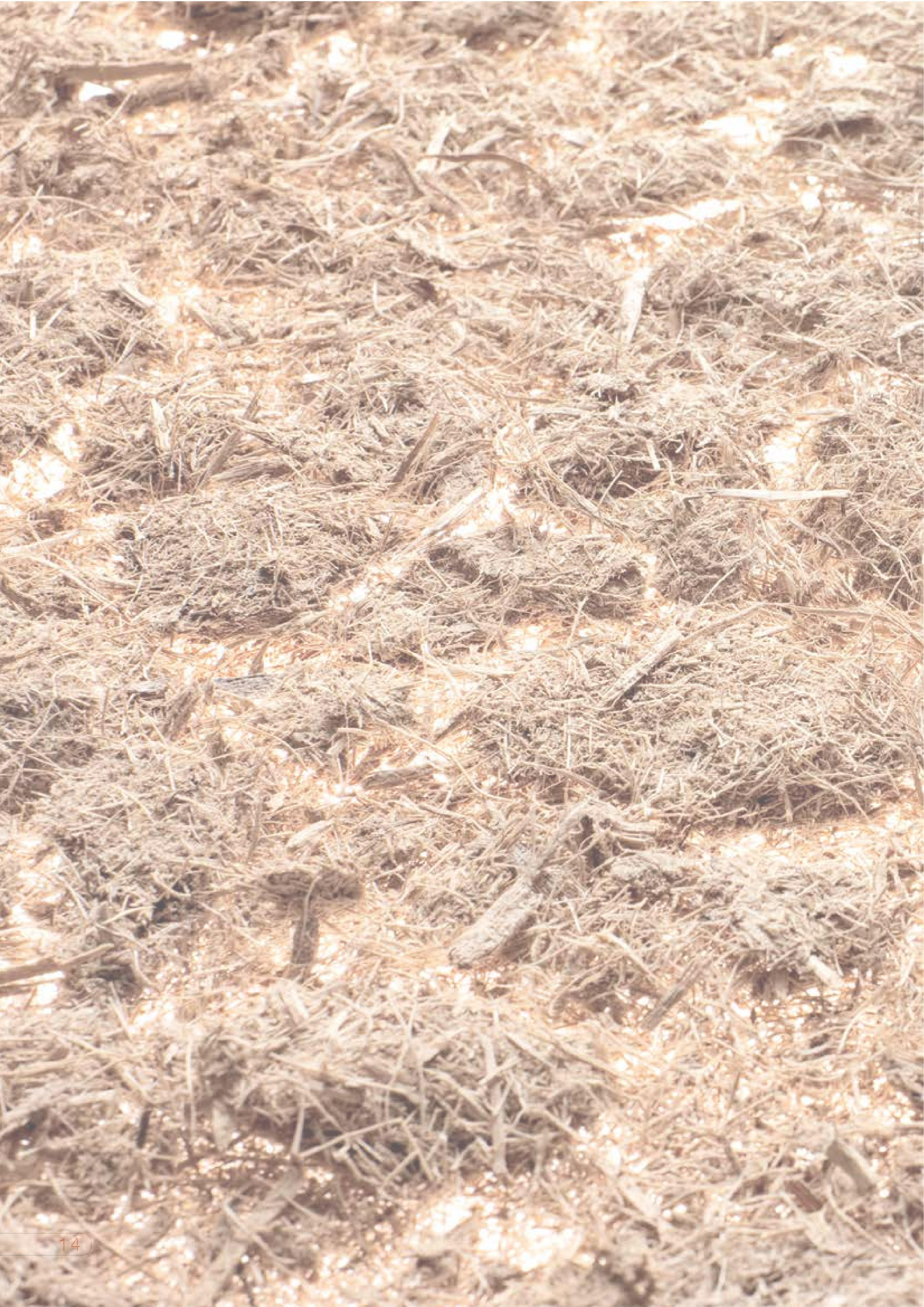
The carbon in un-decomposed forest residues would be released if used for bioenergy, and thus this can be seen as a carbon loss when considering emissions over a 20-year project timeframe. If the timeframe considered were longer, the estimated carbon loss would be smaller. This analysis assumes that 10 per cent of slash will remain un-decomposed at 20 years if not removed for biofuel production.

Previous analysis shows a wide range of results for soil carbon loss. Several empirical studies fail to find evidence of a statistically significant increase in soil carbon loss from the removal of slash[6,7].

However, several modelling studies do suggest that slash removal might lead to increased soil carbon loss[8,9,10]. In the absence of clear evidence, this study assumes no carbon loss for slash removal in the central case, but it also examines a sensitivity case where 3 tonnes of carbon per hectare is lost.

Since both agricultural residues and (to a lesser extent) slash contain macro-nutrients such as nitrogen, phosphorous and potassium, their removal from fields or forests results in loss of nutrients that would otherwise return to the soil. This implies that to maintain soil fertility, inorganic fertilizers, manure or other residues should be applied to compensate for nutrient loss. N_2O emissions from fertilizers have a particularly significant climate impact.

While in some cases farmers might choose not to fully replace lost nutrients, the analysis in this project calculates the emissions associated with full nutrient replacement.



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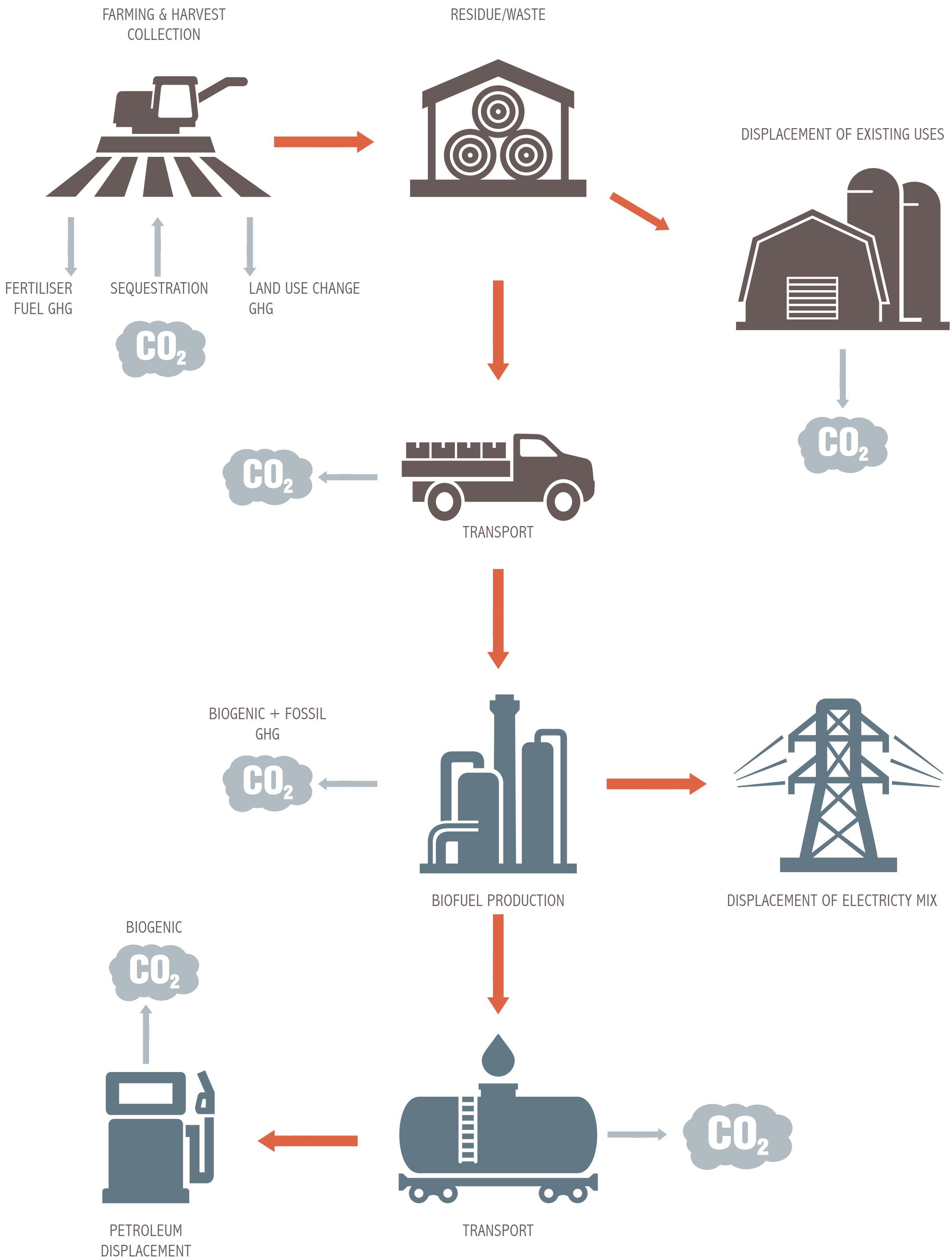

GHG impact of displacement

Many types of residues already have uses, ranging from straw for livestock to woodchips for fibreboard to incineration for energy. Depending on the degree to which each resource is already utilized, diverting these resources for use as biofuel feedstock could cause displacement effects leading to indirect GHG emissions.

Although in principle feedstock demand could be met through using unused residues, in the real world it is likely that a certain portion of biofuel may come from residue that has already been collected for other purposes. In line with the conservative approach taken in this project, it is assumed in this LCA that half of the utilized agricultural residues come from increased collection and the other half come from displacing existing uses.

By contrast, for slash there is no existing use, and therefore no displacement is considered. For sawdust, it was assumed that all use for biofuels leads to displacement, as sawdust is currently burned for electricity or used in construction materials and furniture.

Where existing uses are displaced, the analysis in this project assumed the shortfall would be compensated by using either Miscanthus or willow. In reality, there would be a wide spectrum of possible downstream displacement effects and responses, and this is an area where further analysis would be valuable.

Miscanthus is a fast-growing perennial crop that has a relatively high expected yield of about 8 tonnes per hectare in large-scale commercial plantations. Provided food prices remain significantly higher than Miscanthus prices, farmers are likely to plant Miscanthus on land that is not used for food production. Miscanthus sequesters significant amounts of carbon into the soil via its roots and this outweighs the other emissions, such that the overall emissions factor is negative over a 20-year timeframe (-0.4g CO_2e/MJ). The carbon intensity would be significantly higher if planted on fertile agricultural land, due to indirect land use change.

In the case of willow, the emission factor is positive (9g CO_2e/MJ), since carbon sequestration is not large enough to offset the emissions from its farming, harvest and transport.

While displacement impacts generally lead to increased carbon intensity, the converse is true when conversion of residues to biofuel prevents them from decomposing to the potent GHG methane. In many parts of Europe, municipal solid waste goes to landfills, where it would decompose to methane. Therefore, its conversion to biofuel offers significant additional GHG savings. For this pathway, the displacement GHG emissions for ethanol from municipal solid waste amount to -225g CO_2e/MJ. Similarly, leaving rice residues to decompose would lead to methane release, and therefore converting rice straw to bioethanol generates a significant GHG credit.

While displacement impacts generally lead to increased carbon intensity, the converse is true when conversion of residues to biofuel prevents them from decomposing to the potent greenhouse gas methane

Life Cycle Assessment Results

Most of the biofuels from wastes and residues examined in this project were found to deliver significant GHG savings compared to fossil fuels.

Biofuels derived from agricultural residues were found to offer GHG savings of around 80 per cent in most cases, ranging from 73 per cent for rapeseed straw ethanol to 173 per cent for rice straw ethanol, when compared to diesel or gasoline at 83.8g CO_2e/MJ. Even if avoided methane is overlooked for rice straw ethanol, it still delivers GHG savings of around 80 per cent.

When using agricultural residues via the FT-diesel pathway, GHG savings ranged from 77 per cent for rapeseed straw to 176 per cent for rice straw. Similarly, diesel obtained from fast pyrolysis of agricultural residues led to GHG savings of 80 per cent for rapeseed straw to 140 per cent for rice straw. Forestry slash offers reasonable carbon savings depending on the pathway chosen, reaching as high as 61 per cent for pyrolysis diesel.

For sawdust, GHG savings range from 74 per cent in the pyrolysis diesel process to 78 per cent in the biochemical ethanol process. This is despite the significant displacement emissions when sawdust is diverted from existing uses to biofuel production. Without the displacement effects, GHG savings could reach almost 100 per cent. GHG savings are even more significant for municipal solid waste due to the GHG credit for avoided methane, leading to GHG savings as high as 296 per cent.

In conclusion, the evidence presented in this chapter shows that many advanced biofuels from wastes and residues can make a significant contribution to mitigating climate change, even when taking account of losses to soil carbon, displacement effects and the need for additional fertilizers.

Many advanced biofuels from wastes and residues can make a significant contribution to mitigating climate change, even when taking account of losses to soil carbon, displacement effects and the need for additional fertilizers

This chapter summarizes the project's assessment of which waste and residue feedstocks are most sustainable and in what volumes. A more detailed analysis can be found in the paper "Availability of cellulosic residues and wastes in the EU", Searle S and Malins C, 2013
International Council on Clean Transportation

Availability

Availability of crop residues

Considerable volumes of crop residues are produced in the EU, including field residues such as stems and leaves of grain crops, and processing residues such as chaff, husks and cobs. This study assesses availability of the EU's 12 most produced crops using data from the Food and Agriculture Organization of the United Nations Statistical Division (FAOSTAT) (2002-2011).

With modern harvesting technology – combine harvesters that cut, separate and thresh the grain – almost all residues remain in the field. However, not all residues should be considered available for bioenergy. It is widely acknowledged that a fraction of residue should remain in the field to maintain moisture, reduce erosion and protect soil carbon, nutrients and soil structure. In addition, a fraction of residues are currently collected and have other uses, mainly for animal bedding.

Unfortunately, there have been relatively few experimental studies in the EU on the impact of removing residues, and a review of those studies that have been undertaken found significant variation[11]. In the absence of a detailed evidence base, this study relies on the current "best practice" of leaving one-third of total residues in the field, as advised by the EU Joint Research Centre[12]. This is consistent with the current practice of many European farmers, but it is important to stress that the ideal residue retention rate varies by location, soil type, slope, erosion, precipitation patterns, etc., and should be determined on a local level.

A proportion of those crop residues that remain available have existing uses, such as bedding and fodder for livestock, mushroom cultivation and other various horticultural uses. The proportion of residues used for livestock rearing varies widely between European countries, with estimates as high as 42 per cent in the UK (ADAS) and as low as 11 per cent for the EU overall[13]. The wide variance in estimates is likely to reflect regional differences in farming techniques. This project conservatively assumes that one-third of available residues have existing uses. While this approach might result in an underestimate of availability, it allows reasonable confidence that this quantity of material is indeed sustainable.

Based on the assumption that one-third of residues must remain in the field to maintain soil quality, and one-third must be left for existing uses, this study estimates that around 122 million tonnes of agricultural residues are currently sustainably available. Estimates of future availability are extrapolated onwards from the European Commission's 2012 projections of increased agricultural production to 2022. In 2030, this study estimates 139 million tonnes of agricultural residues will be sustainably available, broadly in line with a recent estimate of 155 million tonnes[14].

These numbers are also within the range of other estimates, from 35-53 million tonnes at the low end[15] to 182-229 million tonnes at the high end[16].

Availability of forestry residues

During logging, a significant fraction of the tree – leaves, small branches and stumps – is discarded. These forestry residues are bulky, difficult and expensive to collect and transport, and currently have little commercial value. However, if the market for renewable energy made collection profitable, some of this material could be made available.

The ratio of residues to harvested wood varies widely with species and harvesting technique, but there is consensus in the forestry sector that, on average, about half of any tree is discarded[17]. Scientific literature estimates residues are in the range of 30-50 per cent[18,19,20].

This study uses the assumption from Mantau (2012)[21] that 24 per cent of the tree is discarded as residues, on the grounds that this is a recent publication that is likely to reflect modern harvesting techniques in Europe, and also that it provides a conservative estimate in line with the priorities of this project.

Total residue availability was calculated from FAOSTAT records of EU roundwood production from 2002-2011, leading to an estimate that around 80 million tonnes of forestry residues are produced annually in the EU.

Using all the residues from forestry would mean that nutrients, which are concentrated in the leaves, are no longer returned to the soil, resulting in lower tree growth in subsequent years[22,23,24,25,26,27,28]. Leaving stumps to protect against erosion and leaves to return nutrients to the soil would help mitigate these impacts. Current practice is to leave the needles and leaves in the forest when branches are collected. To estimate forestry residue availability, this study has assumed that it is sustainable to harvest 50 per cent of available residues if combined with good land management practices.

Over the last decade, timber harvesting remained broadly constant. While population growth would suggest an increase in future harvesting, there is also some evidence of a decline in per-capita use of timber. Meanwhile, the long-term growth of competing uses of biomass for heat and electricity generation to meet the EU Renewable Energy Directive remains unclear. This study therefore assumes that sustainable availability of forestry residues in 2030 remains broadly unchanged from today – at around 40 million tonnes per year.

Municipal Solid Waste

European households dispose of around 150 million tonnes of biogenic material each year – mostly discarded wood, paper, food and garden waste. Some of this material is then recovered and recycled or incinerated for heat and power. In many EU countries, the rest is permanently disposed of, typically to landfills. The fraction of waste that can most sustainably be used for biofuel is that which would not otherwise be recovered for any use – in particular that which would otherwise be landfilled.

Generation of Municipal Solid Waste is projected to continue increasing (EEA, 2011), but rates of recycling are increasing at a faster rate, leading to an overall decrease in available volumes between now and 2030.

Paper and cardboard is usually discarded after 1-2 years, and about 81.5 million tonnes were consumed in Europe in 2011, according to the Confederation of European Paper Industries. The waste hierarchy prioritizes recycling above energy recovery because materials are considered to have a higher value when recycled than that reflected by their raw energy content alone, so use of the recycled fraction of municipal solid waste is not considered sustainable. About two-thirds of paper and cardboard is either recycled, composted or incinerated with energy recovery.

Nevertheless, about 17 million tonnes a year of paper waste are estimated to be sustainably available, reducing to around 12 million tonnes annually by 2030 as recycling rates improve. Estimates of the wood fraction of Municipal Solid Waste, for example discarded furniture or renovation debris, are in the range of 26-57 million tonnes per year[29,30]. Of this, around 40 per cent is recycled into other products and around 50 per cent is burned for energy, leaving just under 10 per cent available as a potential feedstock for advanced biofuels. Therefore, about 6 million tonnes a year of wood waste are estimated to be sustainably available in 2030.

Households and businesses also produce a considerable amount of cellulosic material in the form of unused food and garden waste, such as lawn and tree cuttings, with previous estimates in the range of 50 million tonnes per year. Recycling and composting are likely to increase in future years, such that around 44 million tonnes of household and garden waste is estimated to be available in 2030.

Used Cooking Oil

There is already significant and sustainable conversion in the EU of used cooking oil (UCO) to biodiesel. In some countries, such as Germany, there are existing controls on UCO disposal, and using more of it as biofuel feedstock could have some displacement impact. However, in general UCO is still an under-utilized resource. Processing into biofuel can therefore be expected to deliver significant GHG reductions.

It is challenging to find reliable data on the size of the future potential market, due to the fact that the industry collects from a widely distributed network of restaurants. This is especially the case in developing countries. Nevertheless, there is clearly a large resource and potential for expansion. Industry analysts estimate that more than 1.1 million tonnes of UCO was consumed in Europe in 2013. Similarly, the United States Department of Agriculture (USDA) reports consumption of 1.225 million tonnes of UCO feedstock in Europe[31].

Of this volume, about 700,000 tonnes per year are estimated to come from within the EU, but there are also substantial imports of UCO. Eurostat reported over 250,000 tonnes of imported UCO in 2012, largely coming from the United States. Increased collection in the future is likely to be offset by more efficient use. Major growth in UCO supply is therefore likely to require the introduction of home collection, which would require some behaviour change. If cost-effective, supply could also come from harvesting oils from wastewater, which could offer significant environmental co-benefits.

There is also a large potential for increased imports, as in many regions UCO collection is poorly established. In Turkey, for instance, one estimate suggests that only a tenth of the waste oil produced is being collected.
In the UK, UCO from 47 countries was used as a feedstock last year[32]. A robust chain of custody and proof of origin – for instance through one of the certification schemes operating in the EU currently[33] – would be needed to prevent malpractice and safeguard the credibility of the UCO fuel market.

Conclusions

A significant volume of wastes and residues are generated in Europe each year – around 900 million tonnes. However, much of these “waste” streams are already being used as low-value inputs for industrial and agricultural processes and cannot be diverted to bioenergy production without secondary impacts on downstream markets. Some proportion of these “wastes” play a valuable environmental role in protecting soil quality, preventing erosion and supporting biodiversity. Taking these points into consideration, this project estimates that 223-225 million tonnes of biomass is technically available as a feedstock for advanced biofuels. To put this in context, if all this material were converted to biofuel at current yields, it could supply 36.7 Mtoe per year of liquid fuel, equivalent to 12 per cent of current road fuel consumption, or 16 per cent of projected consumption in 2030.

There will in reality be competition between different energy users. To ensure this resource is deployed most effectively, policymakers might in the future need to make choices regarding the value of low-carbon mobility versus other demands.

This chapter summarizes an analysis by the National Non Food Crop Centre (NNFCC), which is presented in greater detail in the report "Use of sustainably-sourced residue and waste streams for biofuel production in the European Union: rural economic impacts and potential for job creation", NNFCC, 2014

Economics

Crop residues

Wheat and barley straw are commonly traded in Europe for use in the livestock sector. Small amounts are also used in the horticulture sector. While straw is a relatively low-bulk density product, this does not prevent intra-EU trading, which has involved transport of significant tonnages across long distances.

In areas of high demand, straw can be collected on up to 80 per cent of the barley area and 60 per cent of the wheat area. If not collected and removed, it is typically ploughed back into soil.

There are a number of issues that affect the price of agricultural straw residues, such as transport costs and the impact of weather on supply. As an example, Figure 5.1 shows the variability in wheat straw costs experienced in the UK in recent years.

Wheat and barley straw prices also vary significantly between EU Member States. Cereal straw is scarce in the Netherlands and straw prices are high, at around €110-120 per tonne, reflecting that most straw is imported. Prices in eastern and southern Europe can be as low as around €25-40 per tonne, reflecting lower labour costs.

Where straw is being used for heat and electricity, buyers have developed long-term supply contracts with growers. These offer longer-term security to farmers, but the price on offer can be €20-30 per tonne below that on the open market. The development of advanced biofuels creates opportunities to develop more efficient supply chains, supplying reliable markets with long-term contracts for straw.

A straw price of €60-80 per tonne (delivered) is a reasonable estimate for northern Europe, and €30-40 per tonne would be more typical for southern and eastern Europe. Cost for collection, transport and replacement fertilizer can amount to €30 per tonne. Taking all these issues into account, the actual profit margin for the farmer is likely to be only a few euros per tonne at residue prices of €30-40 per tonne, although this margin rises to €28-43 per tonne in areas where farmers can charge €60-80 per tonne for straw.

Forestry Residues

The largest reserves of forest residue resources are to be found in Finland, France, Germany, Poland, Spain and Sweden. However, with the exception of Finland and Sweden, these residues are currently not collected. Where costs have been estimated, these tend to be higher in Northern Europe, reflecting the mechanized approach adopted for collection, and lower in Eastern Europe where labour costs are lower.
Harvest residues are typically collected in bundles and then either stored or chipped at the roadside. Efficiency can be improved by chipping at a central 'receiving plant' before onward shipping to the end user.

Different collection techniques and supply chains lead to wide variation in estimates of cost. The PIX Bioenergy Forest Biomass index, which is based on real material trades in Finland, shows prices of €62.5 per tonne, but other studies show costs as low as €25 per tonne, especially in areas of low labour cost. Transport of forest residues adds around €8-12 per tonne to the delivered price for a trip of up to 100 kilometres (km)[34]. It is uneconomic to transport chips more than 200km over land. These costs are in line with current market prices for industrial wood chips of around €59-65 per tonne[35].

Municipal Solid Waste

Given the wide range of contaminants in municipal solid waste, biofuel plants are likely to rely on a steady stream of pre-sorted waste, known as Refuse Derived Fuels (RDF). RDF, in addition to wood and paper, will also contain plastic and other fossil-derived combustible materials that cannot easily be removed by recycling processes. Only a proportion of the feedstock, and therefore any biofuel produced from it, can therefore be classed as 'renewable'. However this is typically much greater than 50 per cent, and can be as high as 80 per cent, depending on the sorting and separating technologies used.

Use of RDF is compatible with advanced conversion processes utilizing thermochemical conversion, but its heterogeneous nature makes it less suitable for biochemical processes. Waste handlers and processors incur charges to dispose of such waste via landfill, and therefore biofuel operations might be able to charge a gate fee in the range of €20-40 per tonne for accepting the material. The low end of this range is typical for areas where RDF is currently used for power generation, indicating that increasing bio-energy investment could ultimately lead to lower gate fee revenue for accepting RDF.

Impact of feedstock costs

The business case for advanced biofuels from wastes and residues is highly dependent on access to a cheap and reliable supply of feedstock. Figure 5.2 shows the economic incentives that would be required to make biofuels from agricultural or forestry residues competitive with those made from food crops. In regions where feedstocks are cheapest (€30-40 per tonne), little or no incentives are required to make biochemical ethanol cost-competitive with first generation biofuels. By contrast, in regions with high feedstock costs (at €80 per tonne), this industry is unlikely to take off without sustained incentives.

Biofuels derived from municipal solid waste are cost-competitive even with zero gate fee receipts. In cases where they could charge gate fees at current levels of around €20-46 per tonne, the ethanol or FT-diesel produced should be saleable at a competitive price (see Figure 5.3). However, compensation is required to cover the lower value fossil-derived biofuel produced as a co-product (from fossil contaminants in the waste stream, which are likely to be traded at a discount to bioethanol).The barriers to investment are largely a result of policy uncertainty and investor attitudes to risk associated with technologies that have not been demonstrated at large scale.

Impact on the rural economy

Up to €15 billion could flow into the European rural economy if all the available agricultural and forest harvest sustainably resources could be utilized at the price-range identified (€40-80 per tonne for agricultural residues and €40-65 per tonne for forest harvest residues). This would flow back through the whole feedstock supply chain, including the supporting logistics operators, machinery suppliers, contracted equipment suppliers, etc.

Taking account of the costs beyond the farm gate – mainly replacement fertilizer and transport – net revenues of up to €5.2 billion annually would flow to the farming community. In the case of forestry, the net return would be up to €2.3 billion annually.

This project has also sought to estimate the amount of employment that would be created in rural economies as a result of utilizing wastes and residues for advanced biofuels. Using typical work-rates in the agricultural and haulage sectors, it was estimated that 470-680 workers would be needed annually to process 1 million tonnes of feedstock over a year. Previous studies in Scandinavia[36,37] have estimated between 340-620 workers would be required to shift 1 million tonnes of forestry residue, although it should be noted that Scandinavian forestry systems are highly mechanized and would therefore be at the low end of the range of employment intensity.

FIG 5.1

Seasonal and annual variation in UK big bale wheat straw average price (£ per tonne ex-farm, good quality) (source: UK Hay and Straw Traders Association)

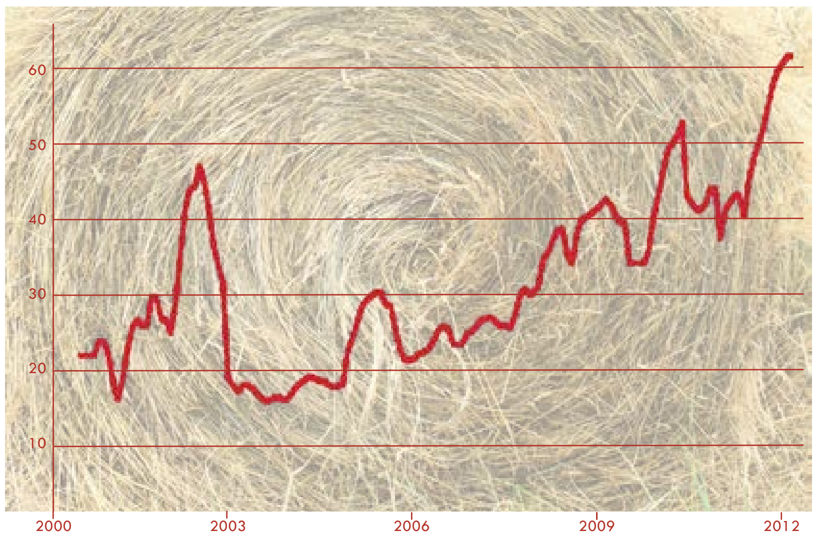

FIG 5.2

Effect of feedstock price (€ per tonne) on the incentive required over and above the anticipated base fuel market price to achieve an internal rate of return (IRR) of 10,15 and 20 per cent for biochemical ethanol processes using agricultural or forestry residues.

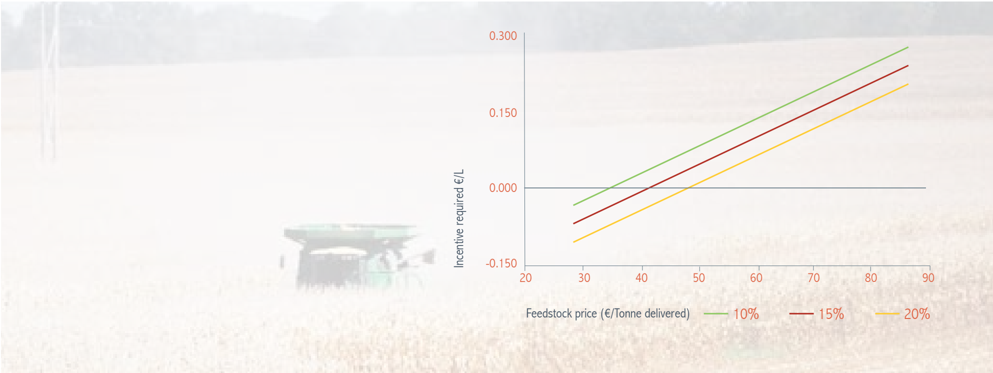

FIG 5.3

Effect of feedstock price (€ per tonne) on the incentive required over and above the anticipated base fuel market price to achieve an IRR of 10,15 and 20 per cent for FT-diesel process using municipal solid waste.

As with most refining of fuels, there is low labour intensity associated with operating a bio-refinery (around 50-80 full time employees per plant), but significant levels of temporary employment are created during the construction phase. For example, the Vivergo wheat-to-ethanol plant, which recently opened in the UK, created about 1,000 jobs in its construction phase.

Based on the level of feedstock availability estimated in Chapter 4, it is possible to estimate the full potential for job creation from developing an advanced biofuels industry in the EU using sustainable wastes and residues as feedstock. To make full use of this resource, in the range of 87-126 thermochemical biofuel plants would be needed, each requiring around 300,000 tonnes of feedstock annually. Alternatively, in the range of 105-162 biochemical ethanol plants would be needed for around 150,000 tonnes required annually.

On this basis, 56,000 to 133,000 permanent jobs would be created in the rural economy if the full potential of wastes and residues were developed in the agricultural and forestry sectors. In addition, construction of these biofuel plants would require 87,000 to 162,000 temporary workers. Operation of these plants would create 4,000 to 13,000 permanent jobs.

It should be noted that in reality, competition will be high from the heat and power sector, and utilization is unlikely to take off in all regions. Furthermore, reaching this scale would require a sharp increase in investment. Therefore the real creation of direct jobs will be much lower than the full potential.

These represent only the direct employment associated with feedstock collection, transport and processing. Additional indirect employment would flow though machinery suppliers, fuel suppliers and other ancillary industries, significantly increasing the overall employment impact in the EU.

Conclusions

This analysis highlights that it is feasible to develop a biofuel industry based on use of agricultural and forest residues, which in the case of the cheapest feedstocks could become cost-competitive with only modest incentives. Such fuels would have the added advantage of avoiding land-use change impacts. Similarly, refuse-derived biofuels could be cost-competitive without further support, as long as feedstocks are available at little or no cost. However, some support would be required to compensate for the lower returns anticipated for fuels derived from the fossil component of refuse.

Chapter 4 demonstrated that converting all the sustainably available wastes and residues to road transport fuels could in theory deliver technical potential of 16 per cent of demand in 2030 if a rapid and large scale investment programme could be put in place. However, in reality the volumes would be lower due to problems mobilizing the entire resource at reasonable cost and investing in the large number of biorefinery plants required.

While utilising all of the available resource might be viewed as optimistic, achieving just 2 per cent of EU road transport fuel in 2020, as suggested by the European Parliament, would be less challenging.

Such a level would secure up to an additional 38,000 permanent jobs in the rural economy and 3,700 more jobs in biofuel refineries, with the potential to return up to €1.1 - 2.4 billion in net revenues to the agricultural and forestry sectors.

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"Assessing the climate mitigation potential of biofuels derived from residues and wastes in the European context" Baral A, Malins C, 2014 International Council on Clean Transportation.

"Availability of cellulosic residues and wastes in the EU", Searle S and Malins C, 2013 International Council on Clean Transportation.

"Use of sustainably-sourced residue and waste streams for biofuel production in the European Union: rural economic impacts and potential for job creation", NNFCC, 2014.

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